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The potential impacts of extracting shale gas on water resources in Algeria

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Abstract:
As Algeria is one of the promising countries in the world in the arena of the size of shale gas resources, the concerns about its potential impacts on the environment triggered a hot debate between the government and the opponents of the development of shale gas. The present paper attempts to determine the potential impacts of extracting shale gas on water resources. To do so, the authors discussed the main concerns expressed by the environmental associations especially the impacts of hydraulic fracturing on water resources trough quantifying the quantities of water that would be used by Sonatrach to drill wells and frack them hydraulicly on the one hand, and as a second step, discuss the major source of concerns and controversy of potential impacts on water quality on the other hand. The main finding of this paper is that extracting shale gas entails only a small fraction of the water resources and will not affect the quality of groundwater if the extraction technique is properly handled.
Keywords: shale gas, water resources, depletion, contamination, hydraulic fracturing.
JEL Classification: K32; Q25; Q35; Q51; Q53

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Introduction

The boom of shale gas has triggered a hot discussion among politicians, economists, and environmentalists about the negative impacts that this source of energy may have on the environment and public health.

These concerns and others are being discussed in every corner of the world where there exist potential shale gas deposits. However, these concerns differ from region to region and from country to country, according to the major and most potential impacts that developing shale gas basins in those countries may result in.

With respect to Algeria, which is one of the promising countries in the arena of shale gas, the major concerns that led some people to oppose shale gas development projects, are the issues of water depletion and water contamination.

The questions of the study

The present paper attempts to answer the following questions:

- Does shale gas extraction require big amounts of water?
- Will shale gas be extracted at the expense of other sectors in term of water use?
- Does shale gas extraction impact the quality of water?

Hypothesis of the study

Extracting shale gas requires big quantities of water;

As any activity, extracting shale gas may impact negatively the quality of water.

Rationale for the study

One of the main purposes of this paper is to assess the impacts of shale gas, particularly, on the quantity of water in Algeria as well as to clarify some points that led to the controversy of the issue of extracting shale gas.

Innovation

The paper at hand will address this issue through following this methodology: the authors will first discuss the main reasons for the controversy debate on the impacts of hydraulic fracturing. Then, by using the findings of the latest scientific papers published in the arena of hydrology, the impacts on the quantity of groundwater will be determined. Finally, the authors will extend the analysis and assess the economic viability of developing shale gas in Algeria from a macroeconomic standpoint. To the best of our knowledge, this is the first time this issue is to be addressed in such a manner.

1-Shale gas: definition, characteristics, and technology used

1-1 what is meant by shale gas?

First of all, since shale gas is a form of unconventional source of energy, we have to clarify what is meant by unconventional energy.

According to information handling service company (IHS) unconventional refers to hydrocarbon resources that cannot be produced at economic flow rates or that do not produce economic volumes without artificial stimuli and special recovery processes and technologies (Ahmed & Meehane, 2016, p 2-4).

In the same vein, the national petroleum council defines shale gas and other types of conventional gas as follows (Perry & Lee, 2007, p 5):

"natural gas that cannot be produced at economic flow rates nor in economic volumes of natural gas unless the well is stimulated by a large hydraulic fracture treatment, a horizontal wellbore, or by using multilateral wellbores or some other technique to expose more of the reservoir to the wellbore".

However, it should be noted that Shale gas is a natural gas, but it failed to escape its original source rocks (Zou et al, 2017, p 287; Bjørlykke, 2010, p 464).it is composed mainly of methane and contained in commonly occurring mudstone and shale rocks (Wang et al, 2012, p 1426; Speight, 2018, p 31). Shale gas can be found in these rocks in different forms; it can be stored within the pores of the rock, within naturally occurring fractures, or adsorbed onto the shale minerals and organic matter within the shale (Hyne, 2012, p 472). The last form in which shale gas stored is the adsorbed state (Jing et al, 2011, p 2451; Speight, 2019, p 90).

It is worth noting here, that, unlike conventional gas, which is trapped in porous rocks few kilometers from the surface, in relatively small areas, and in big quantities, shale gas content per rock is small and shale gas reservoirs are dispersed over a large area (Ahmed & Meehane, 2016, p 22-2). Another distinction that can be made between conventional and unconventional gas is the permeability of the rocks in which gas is trapped. Conventional gas is trapped in porous and permeable rocks while shale gas is trapped in very low porous rock of which the porosity is less than 10% and permeability less than 0.1 - MD (Jing et al, 2011, p 2451).

The following points can be concluded from the definition provided above:

- Shale gas basins are extended over very large areas;
- These basins are full of geological formation that are of low porosity and low permeability;
- The quantity of gas absorbed in the rocks is very small;
- The gas does not travel freely and easily;
- That is why special technique (technology) is used to extract gas from the special geological formation.

1-2 Technology used

The extraction of shale gas became technically possible, economically and commercially viable thanks to two types of technology; horizontal drilling and hydraulic fracturing (Aguilera, 2014a, p 230; Sovacool, 2014, pp 252-254).

After drilling the field vertically as it is the case with conventional gas, the process of horizontal drilling takes place departing from the traditional vertically drilled well by 80° to enable better extraction and boost the flow of gas (Wurzer, 2012, p 361; Speight, 2016, p 150). It is possible to drill a range of 8 to 12 and even up to 16 horizontal wells from the traditional vertical well. This is primary to better extract shale gas and reduce the area required for shale gas industry (IGU, 2012, p 24; DOE, 2009, p 47).

Historically, the first horizontal well was drilled in 1929 in the USA (Miskimins, 2019, p 7).

The second technology known as hydraulic fracturing- hereinafter HF- is a technology invented in the USA in the mid1940s, when this technique was conceived by Stanolind Oil and Gas Company, the first field test was conducted in 1947 in the Hugoton gas field in western Kansas and in 1953 a aptent was issued Stanolind Oil and Gas Company[1] (Veatch, 2017, p 4; Ahmed & Meehan, 2016, p 17-1). This technology developed into its actual forms through a partnership between private sector, gas research centers, and the USA department of energy (Aguilera, 2014b, p 76).

HF involves the pumping of fluids at very high pressure down to the well. The process of pumping these fluids results in cracking the rocks in the deep layers of shale gas plays. After cracking the rocks, proppants usually made of sand and some other additives, mainly chemicals, typically between 3 to 12 additives, are injected down to develop the fracture, keep them open, and to reduce the friction in the well (Holloway & Rudd, 2019, pp 50-51).

It is useful to cite the process of extracting shale gas (Holloway, 2018, p 6ff; Speight, 2017, p 224):

- Site preparation and development which involves building infrastructure, installing equipment and production facilities;
- Drilling wells vertically to depth of 3000-4500 meters;
- Drilling horizontal wells from the vertical ones;
- Fracturing the rocks using fluids composed of 90%of water,9.5% of sand and 0.5% of chemical additives.

1-3 Reuse of disposal water

In fact, it is the innovation of HF technology that led to the current opposition to shale gas because it is perceived to have negative impacts on the environment.

[1] This company was one of the predecessors of Amoco (originally standar oil of Indiana), which later in 1998 merged with BP.

Before continuing to proceed the present analysis, it is important to properly define what HF is, since the difference of dentition of HF between the gas industry and environmentalists led to the current controversy and continuing the current hot discussion. The gas industry confines the definition of HF to the process of pumping water, proppants, and additives (Miskimins, 2019, p 1). As such, HF per se is not harmful and does not contribute to the contamination of water. Thus, no company undertaking investments in the shale gas field is willing to admit that it contaminates drinking waters. It, therefore, adheres to the narrow definition of HF.

However, environmentalist and other opponents to shale gas extend the definition of HF to the whole process from the preparing the site to the lifting shale gas up (Birdi, 2017, p 7). The whole process entails, of course, a degree of risks associated with extraction of shale gas.

Since the two parties did not agree upon a common definition of HF, there will be a continuous debate on this topic.

In order to avoid this problem, from now up on, HF will refer to the process of pumping water, sand and chemical additives and the flow back of the used waters.

2-Discussing the environmental concerns

Before proceeding the discussion of the environmental concerns, it is worth noting that these concerns are not about shale gas itself since it is, per se, a natural gas just like the conventional one, but they are rather related to the processes of extracting shale gas, most notably the stage of fracturing the rocks hydraulically.

The issue of extracting and exploiting shale gas and other types of unconventional gas was the topic of a hot debate during the last years between economists, politicians, energy companies, and environmentalists. The pivot of discussion is whether shale gas extraction should be banned or on the contrary, it should be allowed and supported.

The following are some of the concerns expressed by those who oppose the development of shale gas reserves (Speight, 2020, p 944ff):

- Shale gas uses enormous quantities of water which may lead to its depletion;
- Hydraulic fracturing can contaminate drinking water;
- Hydraulic fracturing involves the use of dangerous chemicals;
- Disposal waters can harm the environment as they contain chemicals and even radioactive materials.

In this section, the above-mentioned concerns will be discussed with application to Algeria when it is possible.

2-1 depletion of water resources

HF involves the injection of fresh water deep to the shale formations in order to crack down the rocks and stimulate gas production. The process involves the injection of a range of 3 to 8 million gallon of water, i.e 11356-30283 m^3 (Speight, 2021, p 240). depending on the geology of the plays, the depth and the thickness of rocks

Indeed, if these volumes are regarded as absolute values, the first impression is, that, huge amounts of water are being used by the shale gas industry. However, these volumes need to be viewed in a broader context, i.e in the context of the whole picture of water consumption by other sectors and by other sources of energy. Table 1 below indicates the amount of water needed to produce 1 million British thermal unit (MMBTU) by various sources of energy.

Table 1- quantity of water required to produce 1 MMBTU by different types of energy.

Source of energy	Shale gas	Coal without slurry	Coal with slurry	nuclear	Conventional oil	Enhanced oil	Tar sand	Biofuels
Quantity of water in liters	4-6 233	8-30 255	49-120 --	30-50 370	30-80 147	30-9500 --	102-257 139	>9500 305

Source: Rogers, 2011; Spang et al, 2014, p 3.

The table above reveals clearly that shale gas requires less quantity of water to produce 1mmbtu than other sources of energy do. For instance, while shale gas requires a maximum of 6 to 233 liters per 1 MMBTU[2], coal requires 120 to 255 liters, nuclear energy requires 50 to 370 liters, and the most surprising fact is that biofuels consume more than 9500 liters to produce the same amount of energy.

Thus, it is fair to say that the statement of those who think that shale gas puts water supplies at risks is a misleading statement, especially, when ignoring the quantities used by other sources of energy as it has been just mentioned.

The source of this misjudgment may lay in the fact that shale gas exhibits explicitly the amount of water needed to be injected in its early phases of production, while other sources of energy don’t. For example, conventional oil requires water to be injected for long periods of time in order to maintain the pressure of the reservoirs.

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[2] Clarck et al (2013) in their study found that shale gas in all its life cycle requires a range of 13 to 37 liters of water،

The other source of concerns may well be the availability of water resources and their best allocation to different sectors of the economy. The limitation of water resources and the huge amount of water required to lift up shale gas, raised concerns about the depletion of water resources and led some researchers to consider the projects of developing shale gas reserves as an irrational activity. These concerns are exacerbated in Algeria, which has been classified, by the World Bank, among the poorest countries in the world in the term of per capita water consumption.

The estimation provided by independent researcher are in line with the statements made by the World bank, for instance, according to Bouchentouf & Benabdeli, the ordinary Algerian consume 320 m^3 per year, however, Mennat Allah et al (2020) estimated that per capita water consumption in Alegria is 300 m^3, while Burak & Margat (2016) gave an even lower estimation of 294 m^3 per annum, which is far below the world average of 1000 m^3. As such, managing water resources in Algeria exhibits a strategic characteristic in the pathway of the country toward sustainable development because water is scare and precious resource and entails the rationalization of its use to meet the needs of households and the national economy without putting at risks the needs of future generations (Harouche, 2012).

The estimations of water resources in Algeria vary from study to study according to the timing of study and the methodology used to estimate the quantities of water. In this paper, the authors will follow Drouiche et al (2020) since their study is among the most recent and most detailed ones. Beside they included unconventional sources of water.

According to those researchers, the total conventional waters are estimated to be 17 km^3 distributed as follows (Drouiche, 2020, p 20ff):

- 10 km^3 of surface water located principally in the North of the country, renewed mainly by rainfall;
- 7 km^3 as groundwater, of which1.92 km^3 are located in the North of country and 5 km^3 found in aquifers in the Algerian Sahara in the South. The average annual renewed quantities of the groundwater is about 1 km^3.

The sources of unconventional waters embodied mainly in the forms of desalination, reuse of water and virtual waters.

- *Desalination*: the actual capacity of desalination stations is 2.3 million m^3 daily. The planned and ongoing stations capacity is projected to be 1.2 million m^3.Thus the future desalination capacity will be 620 m^3 million per day.
- *Water reuse*: the total annual capacity was 600 million m^3. The actual capacity since 2020 is 1.2 km^3

- *Virtual waters*: although there are some researchers who argue that virtual waters are not good indicator of optimal strategies regarding water resources, and do not help to meet water need and alleviate water scarcity (Wichelns, 2015; El-Fadel, & Maroun, 2008; Ramirez et al, 2010), yet there are some who stressed the importance of virtual waters in meeting the country need of water. Algeria virtual water imports increased from 10.9 km^3 to 17.3 Km^3 (Drouiche et al, 2012, p 282; kherbache, 2021, p 439).

Actually, the quantities of water are larger than the above-cited estimations. A study published by MacDonald et al, (2012) from the British geological survey indicated that Algeria is among the top five African countries where there exist huge amounts of groundwater. According to this study, the quantity of groundwater in Algeria ranges from 56400 to 243000 km^3 and the best estimates are 91900 km^3 . Even when we take into consideration the statement of other researchers who argue that these quantities cannot be fully extracted and used because of the quality of waters, the nature of sedimentary rocks, technical and the financial barriers that hamper the exploitation of these waters (Edmunds, 2012, p 2ff). This does not apply to Algeria for three main reasons; the first one is that groundwater is classified as high productive aquifers and renewable ones, 5-25 ML per annum (MacDonald et al, 2011, p 1). The second one is that the depth of these aquifers is about 250 meters (Bonsor, & MacDonald, 2011, p 19). Water at this depth can easily be reached and extracted. Moreover, this depth is below the depth of aquifers located in Ain Salah (600 meters) where investment were undertook by the government to extract water. The third one is that Algeria is diversifying its water supply by extending to a non-conventional source of water through investing in building water desalination stations in coastal counties to provide fresh water for different use (Drouiche , 2020, p 33).

It is important to quantify the impact of shale gas extraction on the quantity of water in Algeria. Since no information is available on the real quantities of water required to drill one well in Algeria, we will use the biggest quantity of water required for HF per well in the literature. As it is well known, only two countries in the world proceeded the operations of extracting shale gas, i.e the USA and China. It is also well known that the majority if Chinese shale gas plays are located in Sichuan province, a mountainous and drought area with geological complexity which entails huge quantities of water. Researchers from China estimated that drilling one well requires between 60000 to 71100 m^3 (Zhong et al, 2021, p 7169; Liu et al, 2021, p 11).

In so doing, we will admit that drilling one well requires 71100 m^3, this is more than the quantity stated by the CNLC, which is 20000 m^3. The authors will also admit the statement that drilling a well entails HF process to take place up to 60 times (Aguilera, 2014a, p 228). To calculate the number of wells to be drilled, the authors will determine the whole area of shale gas and not only the prospect area as indicated by the EIA. The whole area is 945605 km^2 (EIA, 2013, p XV-1ff). Then we will use the highest number of well drilled per 10000 km^2 in the world, i.e that of North America; 500 wells per 10000 km^2 . The number of well is 47280 (945605*500/10000). Since the actual extraction of shale gas will take place between 2020 and 2025 (Chourouk, 2015), it is necessary to take into consideration the future available quantities of water, and the future need of water of the different sectors of the economy. The authors will use the lowest quantity indicated by the study of Macdonald et al which is 56400 km^3. Though it is not realistic, but for the sake of simplicity the authors will assume that drilling the well will be completed in one year.

Table2 : the total quantities of water in Algeria in km^3

Water sources	quantity
Surface water Groundwater Unconventional water Desalination Water reuse	12.4 56400 0.8395 1.2
Total quantities	56414.14

Source: the authors 'calculations

Table 3- quantifying the quantity of water required to extract shale gas in Algeria.

Total area ($\boldsymbol{km^2}$) Average number of wells per 10000 Number of wells Amount of water per well ($\boldsymbol{m^3}$) Up to 60 times ($\boldsymbol{m^3}$) Total amount of water for 47280 wells ($\boldsymbol{m^3}$) (1 $\boldsymbol{km^3}$ = 1000000000 $\boldsymbol{m^3}$) the total quantity of water available	945605 500 47280 71100 4266000 201696480000 **201.69** 56414
Ratio to the total available quantity of water	**0.35%**

Source; the authors' calculation

Even when adopting the maximum amount of water necessary to drill one well up to 60 times, and the maximum numbers of wells that can be drilled, and most importantly when admitting the minimum estimation of groundwater in Algeria, the results reveal clear-cut evidence that shale gas uses only a small fraction of the total quantity of water. This is in line with the findings of Nicot and Bridget study (2012) which is based on historical data of water use in Texas. Nicot and Bridget findings show that quantity of water used to extract shale gas in Texas represents only 1% of water withdraws. These findings are also in line with the findings of the most recent studies conducted to estimate the quantity of water required to extract shale gas in Texas between 2005-2014, the author found that fracking used less than 0.5% (Aminzadeh, 2019, p 17). Even in arid areas like the state of Colorado in which HF consumed 16 billion gallons of water, this quantity represents a negligible fraction of total water consumption (Du, 2021, p 282). Furthermore, studies conducted in the UK found that shale gas will make up to 0.1% of total water withdraw (Brown, 2020, pp 142-143). Even in China Which has higher shale gas water footprint, hydraulic fracturing requires only 2% of total water consumption, (Zhang et al, 2019, p 119).

Furthermore, neither the extraction of shale gas nor the use of other sectors will take place at the expense of each other in term of water use. The quantities of water are huge and are enough to meet the needs of every single sector.

In fact, the actual situation is much less acute for the following reasons:

- the bulk of oil and gas industry is concentrated in the South of the country;
- the bulk of groundwater aquifers are located in the South near the centers of oil and gas industry;
- the South of the country is much less populated than the North;
- the bulk of the industrial and agricultural activities are concentrated in the North.
- Most importantly, the number of drilled wells is far less than the number provided earlier on the one hand, on the other, according to the Algerian officials, drilling the wells will last about 7 years and not in just one year, thus the burden on water resources will be less acute.

To sum up, the arguments of those who argue that shale gas threats water supply is misleading, unrealistic and based on a misunderstanding of shale gas industry.

2-2 water contamination

Before proceeding, it is necessary to determine what is meant by contamination, since this is one of the reasons why opponents and proponents of shale gas extraction disagree.

According to Health (1987), contamination is any deterioration in the quality of the water resulting from the activities of man.

Singhal and Gupta (1999) differentiate between contamination and pollution;
Contamination: is used for the addition of any solute into the hydrologic system as a result of man's activity.
Pollution: is restricted to a situation when the contamination attains levels that are considered to be objectionable.
Thus, contamination is the change of the quality of water which may not be harmful, while pollution refers to a dangerous situation.
To determine whether the water is contaminated or polluted, scientists usually measure toxicity either as a mass fraction in part per million (ppm), or a mass of volume in milligrams per liter (mg/l) (Reis, 1996, p 72).
In this regard, it should be noted that these measures and the prescribed standards for drinking water for instance, is not purely scientific, it varies from country to country depending on economic conditions, climate, food habits, and geographical conditions, the different water quality criteria issued by the World health organization, the European community exemplifies this issue (Singhal & Gupta, 1999, p 228).
Moreover, those measures are the results of the experiments conducted in laboratories. These experiments or bioassays have many limitations; first of all, they yield only acute lethal concentrations and provide no data on sublethal or the long-term effects of the tested substances. Secondly, laboratories in which experiments are conducted don't represent the real environment conditions. Thirdly, those experiments consist of exposing the animal or the soil to a single high-level dose of the substance in question, as such, they don't reflect the chronic effects. Furthermore, those experiments and tests are usually conducted off-site which means that samples have to be taken to laboratories, this can lead to a change in the fluid chemistry over time. All these limitations affect the robustness of the results obtained (Reis, 1996, pp 72-73).
It was already mentioned that extracting shale gas involves drilling well down to 4500 meters and deeper if necessary. As it is known, water aquifers found at depth of about 300 meters. This fact, i.e, drilling through water aquifers raised concerns about potential contamination of these waters.
With respect to Algeria and according to the opponents of shale gas, the above situation is more worrying for two reasons. The first one is that the typical depth of water aquifers is 250 meters. The second one is the fact that all water aquifers are located in the same geographical areas where shale gas basins are located.
Those concerns can be justified if drilling through aquifers is not protected and left alone. The fact is that, after drilling the wells, the layers holding water aquifers are not left alone, they are cased and cemented several times

to prevent any potential communication between water and gas and to prevent any leak of proppants or chemicals used to crack down the rocks (Donaldson et al, 2013, p 21; belyadi et al, 2017, p 99ff). If this process is properly handled, then there will be no reasons for fear of water contamination.

Moreover, water aquifers lay in depth of about 300 meters and shale gas is found at depth of 3000- 4500 meters and even more to 6000 meters as it is the case of some shale gas basins in Algeria (Khalaifat et al, 2011, p 18). Therefore, they are totally separated particularly when water aquifers are properly cased and cemented. Furthermore, studies found that artificial fractures don't cause communication between the producing formation and overlying aquifers (House, 2013, p 49; Jacobs & Testa, 2019, pp 188-189; Aminzadeh, 2019, pp 14-15).

Besides, according to the laws of physics including Darcy law, water flows from high to low (Chapman, 2002, p 111; Atangana, 2018, p 20). The low permeability of shale gas formation does not allow the fluids to travel up against the law of gravity to reach aquifers (House, 2013, p 49; Soeder, 2021, p 95).

Perhaps this is the reasons why most studies that have been conducted to determine whether and to what extent HF cause water contamination found no or little evidence that HF process causes the contamination of water (Jacobs & Testa, 2019, p 189). The clearest example is the US National groundwater association (NGWA) study in which no accident of water contamination linked to shale gas extraction or to HF process was registered (NGWA, 2011, p 3). The report of the US environment protection agency (EPA) published in 2004, the agency indicated that "whether unconventional oil and gas development caused water contamination remain uncertain" (EPA, 2004). It should be noted here, that, the study of the environment protection agency was carried out to assess the risks of coal bed methane (CBM) on water quality. As it is well known, CBM is located at a depth lower than shale gas and is close to water aquifers, nevertheless, the agency was unable to find clear-cut evidence that there exists a link between extracting CBM and water quality degradation. In its 2016 report, the EPA concluded that chemical additives used for HF are not toxic and not contaminating water (EPA, 2016, p 5-64).

Published studies found that methane[3] (CH4) percentage in aquifer near to shale gas fields are higher than the percentage of CH4 in aquifers located far

[3] It should be noted that methane can be generated by microbial processes in soils and shallow aquifers, and that the presence of methane in water does not make water toxic, for more information, see Soder (2021).

from the shale gas fields, yet this high percentage of CH4 was not attributed to shale gas extraction (Osborn, 2011; Schon, 2011). This is partially explained by: ① the above-mentioned fact, i.e the Darcy law (the impossibility of communication between gas and water), ②and the existence of natural fractures and holes that allow the movement of gas and other chemical materials through the rocks up to aquifers. This was proved by studying the quality of water in aquifers near gas fields in New York as well as in Arkansas, (Davies, 2011, p E871; USGS & USDOI, 2012; Soeder, 2021, p 96).

This is not to say that accidents and incidents do not occur, on the contrary, there have been some accidents reported in a number of cities and counties in the USA such as Dallas, Alberta, Pennsylvania, however all those accidents were attributed to man errors and not to the technology or the HF technique per se (Heinecke, 2019, p 263ff).

2-3 toxicity of the chemicals

Environmentalists and other opponents of shale gas argue that some chemical additives that are added to the fluids used to crack the rocks are toxic and hazardous and some chemicals are to the scientific community unknown and their reaction in the environment is not documented (Soeder, 2021, pp 33-34). In fact, service companies and oil and gas companies by not making information on those chemicals available allowed the opponents of shale gas to fill the dark closet by every monster available (Soeder, 2021, p 109).

As for the chemicals, the percentages of wells with publicly disclosed ingredients increased from 0 to 95% from 2010-2019 (Hill, 2021, p 3924). Unlike the statements made by the opponents of shale gas that companies use complex and unknown chemicals for HF, it turned out that these chemicals are well known and simple (Soeder, 2021, p 109). Even though the number of chemical additives is not known and is increasing, however studies found that the bulk of these chemicals are not toxic (Elsner & Hoelzer, 2016, p 3290). In other published paper in which 81 chemicals were verified, 55% of these chemicals are organic, 27% are biodegradable (Stringfellow, 2014, pp 51-52).

The most common way to study the quality of aquifers is to measure the total dissolved solids (TDS). Some studies detected 27 chemicals found that TDS in aquifers located near shale gas basins have higher TDS (Clarck et al, 2022, p 1091). However, it should be noted that other studies' findings indicate that the concentration of these chemicals is generally low (Fink, 2020, 262).

In this regard, it is well known that TDS tend to increase with the depth; the deeper (the aquifer for instance), the higher TDS (Jacobs & Testa, 2019, p

192). Besides, TDS as a measure provides a clue, but far from definitive, TDS are rather used as an indication of aesthetic characteristics of drinking water and as a broad indicator of an array of chemical contaminants (Soeder, 2021, p 94; Jacobs & Testa, 2019, p 192).

Proving that the source of contamination is the process of HF is a very difficult task since some natural constituents such as methane and chlorides occur naturally in shallow aquifers near oil and gas fields (Speights, 2016, p 234). Besides, there are many sources of pollution like transport spills, naturally fractured rocks, use of fertilizers, leaks in sewers (Heath, 1987, p 66; Fink, 2020, p 259; Bondu et al, 2021, p 9661).

Perhaps that is why many researchers agree that the impact of shale gas on groundwater quality is a controversial issue (Bondu et al, 2021, p 9662).

2-4 disposal water

After pumping water and injecting proppants and chemicals, an important portion ranges from 20 to 80 % of this fluid flows back to the surface containing a mixture of organic matters, chemical additives and dissolved contents of the formation from which shale gas is extracted, some of these contents contain radioactive elements. The flaw back of these fluids confirms the concerns about contaminating lands and surface water. These concerns are considered realistic if the disposal waters are left per se. The fact is that these waters are handled in a variety of ways including reuse of the water and reinjection or treatment of these waters in special facilities with special technologies and materials (Wines & Mokhatab, 2022, pp 236-237; Zhang et al, 2022, p 9). In fact, the flow back of waters that contain organic and nonorganic matter and even radioactive elements allow the shale gas industry (the treatment facilities) to recover critical metals like lithium and Uranium used in important strategic application like Renewable energy and electronic product, the rate of recovery ranges from 6 to 65 mg/l for lithium in the USA and 33.3 mg/l in China (Luo, 2022, p 4715).

Moreover, recognizing the importance of protecting surface water many agencies have proposed many guidelines of best practice to deal with this issue such as the use of fewer quantities of water, the preclude of using chemicals additives that contain benzene etc. (Stickley, 2012, p 334).

With respect to Algeria, the majority of shale gas basins are located in areas characterized by low population density, less agricultural and industrial activities. This means that problems are not as serious as they are in other countries such as the USA where shale gas plays are located near or within overcrowded areas such as New York, (Marcellus), or Texas (Barnet). Finally, the national company SONATRACH is experienced in dealing with the externalities of petroleum activities and has realized very promising results in protecting waters and, farms and livestock (Dhina & Aron, 2004, pp 12-13).

Conclusion

Shale gas is one of the promising sources of energy for the world in the years to come. As an unconventional source of energy, its extraction requires unconventional methods and techniques to be able to deal with the difficult circumstances and complicated geology of the shale gas basins. The most famous and widely used technology is horizontal drilling and hydraulic fracturing.

Based on the discussion provided above, the following points can be concluded:

- Since HF technology requires the use of big quantities of water, entails the injection of proppants and chemical additives on the one hand. And some pollution incidents happened to appear near or in areas where shale gas is extracted, on the other hand, it has been argued that shale gas extraction is not safe, threats the environment, depletes water and impacts its quality.
- One of the main sources of conflict between unconventional gas industry and environmentalists is the non-appropriate definition of what is meant by HF. This led to the current misunderstanding and controversy associated with shale gas.
- HF per se does not pose any problem and does not harm the environment. It only involves the injection of water and some additives. This does not mean that there will be no risks
- However, the whole process -from installing equipment to extract gas- may pose some risks and may contribute to the degradation of the quality of aquifer waters. This confirms the hypothesis on the impact of shale gas on water quality
- With respect to the quantity of water, it turned out to be that, if 1MBTU is to be generated from various types of energy sources, shale gas is the one that requires the least quantity of water.
- Aquifers can be polluted through the travel of Ch4 through naturally occurring fractures.
- With respect to Algeria, it turned out to be that the major concerns particularly those related to water quantity and quality are overestimated.
- Recent studies indicated that Algeria is among the top five African countries where there exist enough quantities of groundwater
- The calculations of the authors reveal that the maximum quantity of water to be used during the HF process is 201 km^3. This confirms the hypothesis that shale gas extraction needs to use huge quantities of water.

However, this quantity represents only 0. 35% of the total quantity of water resources in Algeria.

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